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Determining stand susceptibility to Western Spruce Budworm and potential damaging effects.

Beverly Bulaon, Entomologist
USDA Forest Service, Forest Health Protection
Northern Region, Missoula, MT

Nancy Sturdevant, Entomologist
USDA Forest Service, Forest Health Protection
Northern Region, Missoula, MT

Introduction

Western spruce budworm, *Choristoneura occidentals* Freeman, is the mostly widely distributed and destructive defoliator in the western United States (Fellin and Dewey 1986). Budworm plays a critical role in forest nutrient recycling and regulating stand composition and structure. Its primary hosts are Douglas-fir, Engelmann spruce, and true firs. Current forest stand conditions and climate in western Montana and northern Idaho are especially favorable to budworm. Historical aerial detection maps show high outbreak frequencies in the combination of forest type and stand conditions found in our Region (Kemp et al. 1985).

Due to a complexity of factors influencing budworm populations' outbreak frequency, duration, and damage are highly variable among stand, and hosts (Van Sickle 1985). Large populations can persist if stand conditions are favorable and host material is available. Prolonged budworm epidemics are found to cause marked reduction in tree girth and height. Zhang and Alfaro (2002) examined cores from host trees experiencing ten years of continuous defoliation by the 2-year cycle spruce budworm (*Choristoneura biennis* Freeman) in north central British Columbia. They found the growth loss period could last for 10 to 16 years, with radial increment loss from 16-21%. However, diameter growth returned to normal 3-5 years following the end of the outbreak period.

Understanding budworm preferences and subsequent damaging affects would help determine appropriate management for future prevention or suppression. Managers could benefit from techniques to determine if lands are susceptible to budworm and to what degree. The most efficient approach would be to evaluate areas at stand or landscape scales using hazard-rating techniques.

Hazard-ratings are used to evaluate the likelihood of insect infestations. These ratings are functional at different scales, and may be

used for setting treatment priorities. Risk refers to stand vulnerability in the event of an insect outbreak, while hazard defines a stand's infestation potential. Bousfield, Wulf, and Carlson (1986) developed a hazard-rating system for WSB for forests in western Montana and northern Idaho. This rating system is a generalized modeling system that integrates stand and site characteristics that influence budworm activity.

The nine variables they proposed are:

- Percent crown cover
- Percent host crown cover
- Percent climax host crown cover
- Relative stand density
- Coefficient of variation of host tree height
- Mean host tree age
- Site quality for spruce budworm
- Regional climate
- Surrounding host type

If the model is accurate, the product of multiplying stand variables will determine the quality of budworm habitat. Accurate predictions and early detection provide time to prepare for insect outbreaks if and when they occur.

Starting in 1976, widespread budworm outbreaks occurred in western Montana and northern Idaho. Budworm activity has been at very low levels since 1990. In 2001, aerial detection surveys found small groups of budworm activity in scattered areas in the region. By 2002 and 2003, more activity had been detected in new locations, while previous locations had expanded. Number of acres defoliated by western spruce budworm increased more than two-fold between 2004 and 2005. In 2005, a total of 453,739 acres containing some level of budworm activity were recorded. We may be in only the early stages of the current outbreak. As noted earlier, budworm outbreaks in Montana and north Idaho have lasted for more than 20 years.

Objectives

The objectives of the study are:

1. Determine the cumulative impact of budworm defoliation on mature host trees (Douglas-fir, Grand fir, Engelmann spruce, and subalpine fir) in terms of tree growth, mortality, and stand composition during the current outbreak.
2. Refine and validate the current western spruce budworm hazard-rating system.
3. Evaluate impact of past harvesting on budworm population trends and defoliation.

Study Sites

Annual aerial detection maps from 1985 to 1991 were used to locate potential study sites. Sites were separated into three defoliation categories: high (seven or more years of consecutive defoliation prior to plot establishment), medium (four to six years), and low (three years or less of defoliation). Study locations were then randomly selected from each category. At four locations, stands were selected that were previously treated as either shelterwood or selection harvests. They are being examined to determine if past harvesting practices affect budworm populations and associated damage.

After conferring with forest personnel, stands were chosen that did not have any proposed management activities for the next decade. Permanent plots were established in 33 stands in western Montana and northern Idaho in 1992, 1993 and 1994. An equal number of stands were selected in each defoliation category, low, medium and high. Stands were representative of forest types susceptible to budworm defoliation. Most are composed of dense stands of mature Douglas-fir with little or no regeneration; or mixed species stands of Douglas-fir and pine, dominated by Douglas-fir. Each stand has 10 variable-radius plots 2 chains apart along transects, using a BAF of 40. A 1/100 acre fixed plot was established at the center of each

variable radius plot. Stands are varying in aspect, slope, and elevation.

Methods

Stand information (aspect, slope, elevation, acreage, stand structure, and vegetation) was recorded during plot establishment using Region One Stand Exam Process (1985). Budworm impacts were estimated through periodic re-measurements of growth (diameter-at-breast height and tree height) and crown condition (crown ratio, crown class, top-kill, and branch dieback). Since plot establishment, sites have been re-measured at about five-year intervals. Flight traps (baited with attractant pheromones) were hung at the center of each plot annually, to monitor population levels through 2004. In 2005, pheromone traps were placed only on plots with high defoliation estimates in 2004. In each plot, defoliation for permanently tagged trees and regeneration was rated annually (based on an ocular method designed by Hostetler 1986).

Data for each stand variable were collected and calculated to rate site susceptibility per site. Hazard-ratings were grouped as: 20 or less are low, moderates are 21 – 30, and greater than 30-high. Ratings are reflective of site conditions for the duration of the study since no treatment or notable disturbance occurred. An analysis of variance was run for each stand variable and hazard-rating value per site, to determine which of the nine variables strongly influences hazard-rating outcomes. Changes in growth loss and crown condition from 1992-1994 were subtracted from 2003 inventories as a means to examine differences over the years, and between high and low hazard sites.

Results

Hazard-rating

Of the nine independent variables, three significantly influenenced hazard-rating values (Table 1). Percent climax crown cover, relative density, and site index values were highly correlated to hazard-rating values. These variables are crucial in determining accuracy of the rating. This correlation found that canopy (host foliage material) and stand density (between tree competition) strongly influenced hazard-rating outcomes more than other variables (Table 1).

Table 1. Correlation analysis of hazard rating versus 1994 permanent plots.

Dependent variable	Independent variable	Dependent mean	Independent mean	Correlation	R-squared	F value	P value
Hazard-rating	Current defoliation	25.42	6.086	0.1084	0.0118	0.7	0.4055
Hazard-rating	Total Defoliation	25.42	5.156	0.257	0.0661	4.17	0.0455
Hazard-rating	Trap catch	25.79	1.019	0.0075	0.0001	0	0.958
Hazard-rating	Percent host crown cover	26.38	92.85	0.2958	0.0875	2.78	0.1062
Hazard-rating	Percent climax crown cover	26.38	78.61	0.517	0.2673	10.58	0.0029
Hazard-rating	Relative density	26.38	59.73	0.4832	0.2335	8.83	0.0059
Hazard-rating	Average host age	26.38	117.8	0.256	0.0655	2.03	0.1646
Hazard-rating	Site index	26.38	1.387	0.4761	0.2267	8.5	0.0068
Hazard-rating	Regional index	26.38	1.145	0.274	0.0751	2.35	0.1358

For the period 1990-2003, sites were rated using variables defined by Bousfield et al. 1986. There was no difference in current defoliation intensity of high-hazard versus low hazard stands. Personal observations suggested some stands that rated low or moderate, received more defoliation than some high hazard stands. Defoliation recorded from ground surveys showed no differences between sites because little defoliation occurred before 2003. However, this trend may change if the outbreak increases in intensity over the next few years, as predicted. In 2005, stands with hazard ratings of less than 20 (low hazard) had very little defoliation but highest trap catches (Appendix 1). One exception occurred in an isolated stand on the Lewis & Clark NF. Most remaining stands with moderate or high hazard ratings (<20) were moderately or heavily defoliated in 2005.

Individual tree and stand conditions

As of 2003, tree growth in high defoliation frequency stands has not been suppressed by budworm activity. Between 1990 and 2003**,** diameter and height growth were not significantly different between years, and between stands that were historically either lightly or heavily defoliated. No recorded mortality of large trees was directly attributable to budworm defoliation, but rather to root disease or bark beetles. However, only within the past few years has budworm defoliation intensified significantly on many permanent plots. Following the previous outbreak, stands that were defoliated for more than 7 years, appeared not to be visibly affected as expected**.**

Regeneration was sparse throughout the permanent plots. Canopy openings were rare, and the few live seedlings found were in poor condition. Most dead seedlings died from overstory suppression or budworm feeding. The only concentrations of live regeneration were found in wide-open areas where large trees were at least 20 feet away.

Treatments

As expected, hazard-rating values between cut and uncut plots at Whitebird and Whitetail sites were different, compared to Titan Gulch and Jimmie New which were similar. However, there were noticeable visual differences in stand density between all treated and untreated plots. Defoliation ratings from 2003 show no difference in budworm preference for any of the plots. In 2005, defoliation on 2 of the 3 uncut plots rated was higher than the cut plots. Neither the Whitetail cut nor uncut plot were defoliated in 2005. Most trees on the fourth paired plot (Whitebird) were killed during the 2003 fires. During 2005, 21 % of trees in the uncut Titan Gulch stand were infested and killed by Douglas-fir beetle, *Dendroctonus pseudotsugae* Hopkins, as compared to none in the adjacent, cut stand.

Discussion

The main purpose of this study was to determine current- and post-outbreak budworm affects on forest structure in western Montana and northern Idaho. If the hazard-rating system is accurate, then stands that receive high values have potential for significant damage if and when a budworm outbreak occurs. In this study, even after almost 20 years of continuous defoliation and a decade of low budworm activity, most of the mature trees in high-hazard sites appeared to have experienced little permanent damage. Mature trees on low-hazard sites appeared unaffected by defoliation. Budworm feeding can have pronounced effects on cone and seed production. Even when defoliation is light, up to 71% of Douglas-fir cones in 13 stands in one study were infested (Van Sickle 1985). In this study, we did not measure affects of budworm on cone and seed production but suspect they are significant. Limited amounts of regeneration were found on most plots.

Budworm-caused impacts are often short-term and mature trees can recover quickly after

populations subside. Studies have shown budworm-caused mortality is usually light but can vary greatly between stands. Mortality is usually limited to smaller suppressed regeneration and pole sized trees, which collect falling larvae from the upper canopy. This mass aggregation can overwhelm less vigorous trees, causing severe branch die-back or loss in height (Ferguson 1988). Tree mortality following several years of consecutive heavy defoliation can ranged between 1 and 53 % at sites in Washington, Idaho, Oregon and British Columbia (Van Sickle et al. 1985).

To date, we have not recorded mortality of mature trees from budworm on our permanent plots. We did record mortality resulting from heavy budworm defoliation on smaller saplings. Mortality of mature trees may increase in future years. Defoliation observed in areas outside several permanent plots was very severe and some mortality was seen.

In one area on the Helena NF near several permanent plots, average defoliation for trees in an unthinned area was 83.5% compared to 41.9% for trees in a thinned area. Forty-two trees in the unthinned unit had greater than 90% defoliation compared to 11 trees in the thinned unit. In general, trees in thinned units appeared greener and to be more vigorous than trees in unthinned ones. Thirty-five trees in the unthinned unit were 100% defoliated. Of these, 18, or 50% had dry phloem and are probably dead. Seven trees, or seven percent, in the thinned unit were 100% defoliated by budworm and therefore have the highest probability of dying within the next few years.

Analysis of the hazard-rating variables suggests that reducing stand density should decrease susceptibility to budworm defoliation. Treatments can be beneficial in areas where budworm populations have historically been very heavy. Carlson et al. (1985) found that defoliation in thinned stands was much lower than in unthinned stands. Dispersing larval mortality increases in thinned stands, due to increased distance between hosts. Vigorously growing stands typically withstand and recover from insect damage better than stressed stands. One of the unthinned stands has 21% of the trees infested and killed by Douglas-fir beetle versus the adjacent thinned stand. Negron et al. (2001) showed that increased stocking density of Douglas-fir was associated with increased stand susceptibility to Douglas-fir beetle.

Brookes et al. (1987) suggests that budworm infestations persist in stands until the internal competitive stress between host trees and immigration of new larvae are both reduced. This allows for the re-establishment of natural enemy regulation which is essential in maintaining populations at endemic levels. He also suggests that epidemics will continue indefinitely in forests of advanced successional stage but may fluctuate periodically based on abnormal weather patterns.

Based on this information, reducing stand vulnerability to budworm defoliation using silvicultural methods or prescribed burning can be accomplished. Reducing number of canopy layers and stand density would reduce stand susceptibility to budworm. Prescribed fire could also be used to reduce stand susceptibility by reducing the intermediate tree layer and stocking density.

This report does not include the affects of the current budworm outbreak (2004-2005) to determine if differences can be found between sites with varying levels of defoliation histories, treatments, and effects; there are other factors that contribute to budworm host preferences and population sustainability that were not explored. Kemp et al. (1985) discussed several studies that found strong correlations between temperature, precipitation, and budworm infestations. Abnormally warm and dry weather patterns often precede budworm outbreaks. Moisture deficiencies and high stocking densities can reduce defensive chemistry of trees and consequently improve nutritional quality of foliage for larvae (Brookes et al. 1987). For the

past seven years, much of Montana has been experiencing unseasonably dry weather. National drought monitors show precipitation is 75% below average for some parts of the state. Therefore, budworm activity in west and central Montana is still expected to increase; ADS records and flight trapping indicate strong potential for current outbreaks to intensify and expand if weather conditions favorable to budworm persist.

This study showed very little differences in tree growth (diameter and height) across permanent plots during the 1990-2003 sampling period. Therefore, following the end of the current outbreak, differences in tree growth and height can likely be attributed at least in part to budworm defoliation. Tree cores will be taken from sample trees on each plot following the end of the current outbreak. A follow-up to this report will include core sample information and possible defoliation effects after the current budworm outbreak subsides.

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Appendix 1. Hazard-rating values, defoliation and trap catches for each location

Site name[1]	National Forest[2]	Hazard-rating[3]	Ave. defoliation-mature trees (2005) (%)[4]	Ave. number of Moths trapped (2005) [5]
Jerry Creek	Beaverhead-Deerlodge	47.00	72.0	12
Jimmie New (Cut)	Beaverhead-Deerlodge	25.71	67.0	5
Jimmie New (Uncut)	Beaverhead-Deerlodge	23.72	83.0	16
Cat Creek	Beaverhead-Deerlodge	38.31	32.0	14
Titan Gulch (Cut)	Beaverhead-Deerlodge	30.54	76.0	18
Titan Gulch (Uncut)	Beaverhead-Deerlodge	29.66	81.0	18
Half Moon Park	Beaverhead-Deerlodge	26.96		41
State Mine	Beaverhead-Deerlodge	34.53	0	3
Moffet Mountain	Beaverhead-Deerlodge	46.69	56.0	15
Blake's Fork	Clearwater	13.05		
Giant White Pine	Clearwater	9.79		
Mission Mountain	Clearwater	34.15		
Skyline Drive	Clearwater	17.44		
Cabin Gulch	Helena	20.69	64.0	31
Gates of the Mountains wilderness	Helena	-----		
Pole Creek	Helena	19.19	0	20
Avalanche Creek	Helena	13.39	4.0	26
Little Shanley	Lolo	10.06		
Brewster	Lolo	36.21		
Cotttonwood	Lolo	21.19		
Buckhorn Saddle	Bitterroot	15.75		
Guide Saddle	Bitterroot	19.15		
Anaconda-Pintler Wilderness	Bitterroot	35.54		
Miller Gulch	Lewis and Clark	29.74	60.0	40

Lion Creek	Lewis and Clark	23.21		
Logging Creek	Lewis and Clark	31.29		
Whitetail (Cut)	Lewis and Clark	8.68	0	5
Whitetail (Uncut)	Lewis and Clark	53.78	0	11
Seven Devils	Nez Perce	-----		
Whitebird (Cut)	Nez Perce	16.05		
Whitebird (Uncut)	Nez Perce	53.78		
Squaw Saddle	Nez Perce	4.48		

[1] Names of sites and associated treatments.
[2] National Forest that each site is located within.
[3] Calculated hazard-rating value using Bousfield et al 1986 method.
4 Defoliation averages for selected sites only.
5 Pheromone trap catches for selected sites only.